

Now, an operation when the electron beam irradiation is used for forming an insulation film will be described here. The electron beam irradiation has the following characteristics that energy is applied to a film material as compared with heat treatment.

First, the electron beam can apply energy that is much greater than heat treatment to a film material. The energy applied by heat treatment is some eV or less at most. In contrast, the electron beam generally used for irradiation treatment or the like has energy of about 5 to 200 keV.

Of course, the electron beam advanced into the film material causes cascade due to collision, and loses energy while generating secondary electrons or X-rays. Because of this, all the energy originally possessed by the electron beam cannot always be directly associated with reaction. However, the energy applied by the electron beam to the film material is kept to be much greater as compared with that of heat treatment.

When the electron beam irradiation has been carried out, the energy that cannot be achieved by heat treatment is applied to the film material, whereby bridge reaction of the precursor of the film material can be effectively advanced or a molecule chain or group that can not be cut by thermal energy can be cut.

When the electron beam irradiation has been

carried out, in general, inter-molecule bridge reaction and molecule chain cutting or group separation take place at the same time. Which of these reactions occur or what rate such reaction occurs at depends on type of material molecule. Further, the electron beam irradiation and heat treatment are combined with each other, whereby, even in the case where molecule chain cutting or group separation takes place, a cutting point is obtained as a new bridge point, and further, bridge advances.

As has been described above, such inter-molecule bridge reaction of a film material and molecule chain cutting or group separation that can not be achieved only by heat treatment can be carried out by using the electron beam irradiation treatment and heat treatment.

Advantageous effect when the electron beam irradiation is used for forming an insulation film with its low dielectric rate will be described based on operation of the above described electron beam irradiation. In bridge reaction due to the electron beam irradiation, high energy is applied, and thus, bridge reaction is effectively accelerated.

Further, effective bridge reaction can be carried out at a low temperature by using the electron beam irradiation. Because of this, an increase of bridge defects or voids due to a thermal stress of a

temperature rise or fall is restrained, and a film with its high mechanical strength is formed.

In addition, from the viewpoint of a molecule structure, bridge at a bridge point that is different from bridge due to heat treatment can be carried out by using the electron beam irradiation treatment. Thus, a molecule structure with its high mechanical strength that cannot be achieved by heat treatment is considered to be produced.

With respect to curing of a coat film using the electron beam irradiation, for example, in PCT National Publication HEI No. 11-505670, as a method for curing an SOG material on a semiconductor substrate, there is disclosed a method for irradiating the SOG material with a electron beam while heating the SOG material at a temperature lower than about 250°C.

In addition, in PCT National Publication HEI No. 11-506872, as a method for curing a dielectric substrate such as siloxane on a silicon wafer, there is disclosed that a film having its excellent dielectric characteristics, density, or uniformity and the like can be obtained by using the electron beam irradiation.

Further, in Jpn. Pat. Appln. KOKAI Publication No. 10-107026, there is disclosed an SOG layer curing method for carrying out an insulation action between metal wires and flatting action by exposing the SOG layer to a electron beam, and then, curing the layer